Inverse filtering of headphones for binaural sound reproduction

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Psychological and Physiological Acoustics: Issues Related to Binaural Hearing, Temporal and Spectral Processing, and Audiological Testing

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Contributed Papers

1:30

2pPP1. Localization of sounds presented over headphones in ambient noise. Mark A. Ericson (Air Force Res. Lab., 2610 Seventh St., Bldg. 441, Wright–Patterson Air Force Base, OH 45433, mericson@falcon.al.wpafb.af.mil), Robert S. Bolia (Veridian, Dayton, OH), and W. Todd Nelson (Air Force Res. Lab., Wright–Patterson Air Force Base, OH)

Sounds produced in everyday environments often interfere with other sounds. In aerospace and industrial environments the interfering sounds are typically diffuse and mask the desired sound. Relatively few studies have addressed the effects of noisy environments on auditory localization perception. Most localization experiments use stimuli presented in the free field, without maskers or with one directional masker. A few studies [Hirsh, J. Acoust. Soc. Am. **22**, 196–200 (1950); Mershon and Lin, Ergonomics **30**, 1161–1173 (1987)] have measured auditory localization perception in reverberant environments. However, in these studies both the signal and maskers were produced in the reverberant environment. With virtual audio systems becoming widely available, many applications will likely involve listening to directional sounds over headphones while immersed in a high-intensity diffuse noise field. The current study examines the effect of bandlimiting various frequency regions of a directional noise signal presented over headphones in the presence of ambient noise. The four signal regions include: (1) 0.1 to 1 kHz; (2) 1 to 4 kHz; (3) 4 to 8 kHz; (4) 8 to 16 kHz. Results from this study have implications for the design of directional audio displays in high-noise environments.

1:45

2pPP2. Inverse filtering of headphones for binaural sound reproduction. Pauli Minnaar and Henrik Moller (Acoust. Lab., Aalborg Univ., DK-9220 Aalborg, Denmark)

Binaural recordings can be made at a blocked ear canal entrance and can be conveniently played back over headphones. The total transmission is then characterized by a transfer function that includes the responses of the headphone and the microphone as well as the transmission between them. The transfer function can be broken up into a minimum phase and an excess phase component, of which the latter can again be broken up into an all-pass and a linear phase component. In order to make the binaural system acoustically transparent, an equalization filter must be designed as the inverse of the total transfer function. The suitability of various filters for inverting each of the transfer function components is evaluated using data from real ear measurements. The robustness of the equalization is discussed with respect to slight changes in headphone and microphone placement. For the investigation 2892 measurements were made on a range of people wearing various types of headphones and wearing different samples of the same type of headphone.

2:00

2pPP3. Loudness perception with headphones versus loudspeakers. Jana Schiffel and Henrik Møller (Acoust. Lab., Aalborg Univ., Fredrik Bajers Vej 7B, DK-9220 Aalborg Ø, Denmark, akustik@kom.auc.dk)

This study examines whether human loudness perception is influenced by the type of sound source, or determined exclusively by the sound pressure received at the eardrum. The literature contains conflicting views on this issue, particularly for the case of listening to earphones compared to, for example, listening to loudspeakers. To begin with, the paper summarizes the controversial results of earlier experiments. Ambiguities and loose ends worth investigating are pointed out; crucial aspects of experimental design are considered, e.g., the test sound material, various ways of binaural versus monaural presentation, and the psychometric method. Following this, new experiments are proposed. They comprise: (1) subjective equal-loudness comparisons (2-AFC) between various types of headphones and loudspeakers at different locations, and (2) probe-microphone measurements of the corresponding sound pressures in the listener's ear canals. Finally, first results are presented. As a practical application, consequences to techniques of headphone calibration are discussed.

2:15

2pPP4. Sensitivity to quantized variations in the amplitude and interaural phase of a stimulus. Douglas S. Brungart (Noise and Vib. Branch, Air Force Res. Lab., 2610 Seventh St., WPAFB, OH 45433-7901, and Dept. of Psych., Boston Univ., Boston, MA 02115, brungart@falcon.al.wpafb.af.mil)

The sensitivities of listeners to quantized changes in the amplitude and interaural phase of a stimulus were measured in two-alternative forced-choice experiments. In the amplitude experiment, listeners heard two diotic stimuli (500 Hz tone burst, 5 kHz tone burst, white noise, speech, or musical chord) that varied in amplitude over a 30 dB range either continuously or in discrete (equal dB) steps and were asked to choose the noisier stimulus. In the phase experiment, listeners heard two 500 Hz tone bursts that varied in interaural time delay (ITD) from -750 μs to 750 μs either continuously or in discrete steps and were asked to choose the noisier stimulus. The amplitude results vary widely across subjects, but indicate that listeners were most sensitive to discrete steps in the amplitude of a sinusoidal signal (threshold step size <0.375 dB), and least sensitive to discrete steps in the amplitude of white noise (threshold step size ≈ 2 dB). The ITD results indicate that the listeners were sensitive to discrete steps in ITD smaller than 2.5 μs. The results have implications in systems which require instantaneous switching between filters, such as virtual audio displays.